United States Government Accountability Office

Report to Congressional Committees

June 2018

F-35 JOINT STRIKE FIGHTER

Development Is Nearly Complete, but Deficiencies Found in Testing Need to Be Resolved

This report was revised June 13, 2018 to correct four figures in table 1 on page 4.

GAO-18-321

GAO Highlights

Highlights of GAO-18-321, a report to congressional committees

Why GAO Did This Study

In 2019, DOD will decide whether to enter full-rate production for the F-35 aircraft, the most expensive and ambitious weapon acquisition program in U.S. military history. DOD has already requested the $9.8 billion it will need for 2019, and it will continue to request more over the next two decades—about $10.4 billion annually. However, the F-35 is just one program in DOD's vast acquisition portfolio, raising questions about its long-term affordability.

The National Defense Authorization Act for Fiscal Year 2015 included a provision for GAO to review the F-35 acquisition program until it reaches full-rate production. This is GAO's third report under this provision. It assesses progress of development and testing, including remaining deficiencies, and plans for spending on new capabilities.

To conduct this work, GAO reviewed and analyzed management reports and historical test data; discussed key aspects of F-35 development with program management and contractor officials; and compared acquisition plans to DOD policies and GAO acquisition best practices.

What GAO Recommends

Congress should consider providing in future appropriations that no funds shall be available for obligation for F-35 Block 4 until DOD provides a sound business case for the effort. GAO is making two recommendations to DOD, including that it resolve all critical deficiencies before full-rate production. DOD concurred with both recommendations and cited that it would resolve all critical deficiencies before its full-rate production decision.

View GAO-18-321. For more information, contact Michael J. Sullivan at (202) 512-4851 or sullivanm@gao.gov.

June 2018

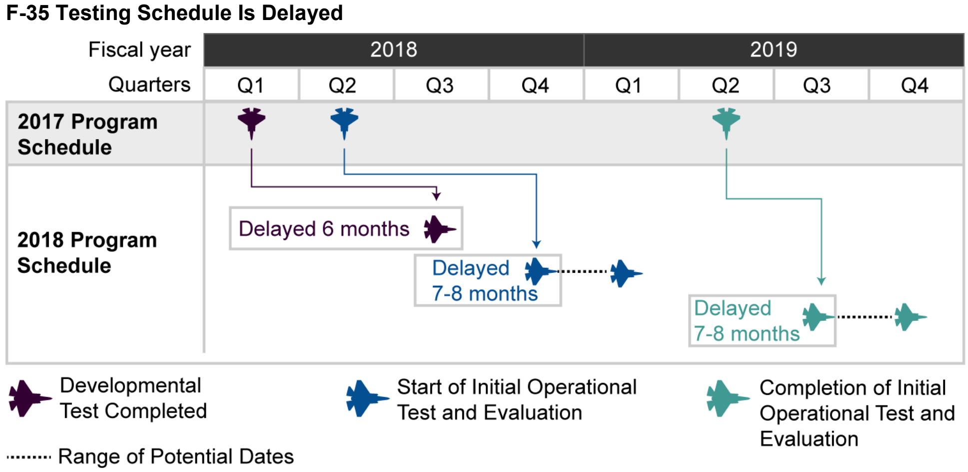
F-35 JOINT STRIKE FIGHTER

Development Is Nearly Complete, but Deficiencies Found in Testing Need to Be Resolved

What GAO Found

The Department of Defense (DOD) has made progress in completing the F-35 baseline development program, but plans to finish testing later than expected.

F-35 Testing Schedule Is Delayed

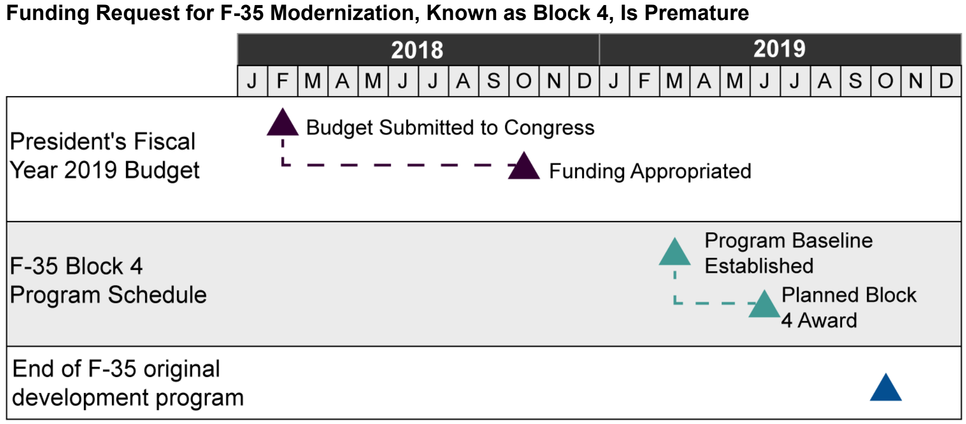


Source: GAO analysis of Department of Defense data. | GAO-18-321

DOD plans to defer resolving some critical deficiencies found in testing until after its full-rate production decision in October 2019, even though DOD's policy states that critical deficiencies generally will be resolved before then. Program officials stated it is reasonable to resolve some deficiencies while in production. Any associated rework could result in additional costs to the government.

DOD plans to spend billions of dollars to modernize the F-35 with new capabilities and is requesting $278 million to begin that process before establishing a sound business case—a baseline cost and schedule estimate.

Funding Request for F-35 Modernization, Known as Block 4, Is Premature



Source: GAO analysis of Department of Defense data. | GAO-18-321

This timing could prompt Congress to make a funding decision before DOD can provide its business case. With these funds, DOD can award a contract, making a long-term commitment to Block 4, the costs of which are not fully understood.

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Abbreviations

ALIS	Autonomic Logistics Information System
C2D2	Continuous Capability Development and Delivery
DOD	Department of Defense
DOT&E	Director, Operational Test and Evaluation
HMD	Helmet Mounted Display
IOC	initial operational capability
LSS	life-support system
STOVL	short takeoff and vertical landing

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June 5, 2018

Congressional Committees

After 17 years in development, the Department of Defense's (DOD) F-35 program is approaching its full-rate production decision, when it will commit to producing 77 aircraft or more per year over the next 12 years. With estimated total acquisition costs of over $406 billion for the entire program, this upcoming milestone will require DOD to commit more of these resources to producing the F-35 Lightning II—also known as the Joint Strike Fighter. Through this program, DOD is developing and fielding a family of fifth-generation strike fighter aircraft that integrate low-observable (stealth) technology with advanced sensors and computer networking capabilities for the United States Air Force, Marine Corps, and Navy, as well as eight international partners.[1] The F-35 program is facing affordability, performance, and reliability challenges, many of which we have reported on since 2001. We have made numerous recommendations for improvement, and DOD has taken action to address many of our recommendations. See appendix I for a table of prior GAO reports, recommendations, and DOD actions. In addition, a list of related GAO products is included at the end of the report.

The National Defense Authorization Act for Fiscal Year 2015 included a provision for GAO to review the F-35 acquisition program annually until the program reaches full-rate production. This is the third report under that provision.[2] In this report, we assess (1) affordability; (2) progress toward completion of development and testing of the baseline aircraft; (3) reliability; (4) manufacturing progress, including supply chain performance; and (5) DOD's plans for a follow-on modernization program.

[1]The international partners are the United Kingdom, Italy, the Netherlands, Turkey, Canada, Australia, Denmark, and Norway. These nations contributed funds for system development and all but Canada have signed agreements to procure aircraft. In addition, Israel, Japan, and South Korea have signed on as foreign military sales customers. The program is developing three variants; the F-35A conventional takeoff and landing variant for the Air Force, the F-35B short takeoff and vertical landing variant for the Marine Corps, and the F-35C carrier-suitable variant for the Navy.

[2]GAO, *F-35 Joint Strike Fighter: DOD Needs to Complete Developmental Testing Before Making Significant New Investments*, GAO-17-351 (Washington, D.C.: Apr. 24, 2017); *F-35 Joint Strike Fighter: Continued Oversight Needed as Program Plans to Begin Development of New Capabilities*, GAO-16-390 (Washington, D.C.: Apr. 14, 2016).

- To assess affordability, we examined the program's past, ongoing, and future initiatives to reduce acquisition costs. We analyzed DOD's selected acquisition reports and its fiscal year 2018 budget request to identify costs, schedule, and performance plans.
- To assess progress in development and testing, we reviewed and analyzed test data and results, program briefings, and internal DOD analyses. We collected data from the past year and discussed key aspects of F-35 development progress, including testing, with program management and contractor representatives, as well as DOD test officials and program test pilots.
- To assess F-35 reliability, we analyzed program office data and monthly reports and compared these to past performance. We also interviewed program office and other knowledgeable DOD officials, as well as contractor representatives.
- To assess manufacturing progress, we collected and analyzed production and supply chain performance data from DOD, Lockheed Martin (the prime aircraft contractor), and Pratt & Whitney (the prime engine contractor).
- To assess the program's modernization plans, we reviewed program documentation and interviewed DOD officials and contractor representatives.

We determined that all the data we used were sufficiently reliable for the purposes of our reporting objectives. Appendix II contains a detailed description of our scope and methodology.

We conducted this performance audit from June 2017 to June 2018 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

DOD began the F-35 acquisition program in October 2001 without adequate knowledge about the aircraft's critical technologies or a solid design, as we reported in March 2005.[3] Further, DOD's acquisition

[3]GAO, *Tactical Aircraft: Opportunity to Reduce Risks in the Joint Strike Fighter Program with Different Acquisition Strategy*, GAO-05-271 (Washington, D.C.: Mar. 15, 2005).

strategy called for high levels of concurrency, or overlap, among development, testing, and production. In our prior work, we have identified this lack of adequate knowledge and these high levels of concurrency as major drivers of the F-35's significant cost and schedule growth, as well as performance shortfalls that the program has experienced since its inception.[4] Since then, the program has been restructured three times. The most recent restructuring was initiated in early 2010 when the program's cost estimates for each aircraft exceeded critical thresholds established by statute—a condition known as a Nunn-McCurdy breach.[5] DOD subsequently certified to Congress in June 2010 that the program was essential to national security and needed to continue. DOD then established a new acquisition program baseline that increased the program's cost estimates and extended delivery schedules 5–6 years into the future. Since completing the restructure in 2012, the program's cost, quantity, and delivery estimates have remained stable, as shown in table 1.

[4]GAO-05-271; and *Joint Strike Fighter: DOD Actions Needed to Further Enhance Restructuring and Address Affordability Risks*, GAO-12-437 (Washington, D.C.: June 14, 2012).

[5]Section 2433 of title 10 of the United States Code, commonly referred to as Nunn-McCurdy, requires DOD to notify Congress whenever a major defense acquisition program's unit cost experiences cost growth that exceeds certain thresholds. Significant breaches occur when the program acquisition unit cost or procurement unit cost increases by at least 15 percent over the current baseline estimate or at least 30 percent over the original estimate. For critical breaches, when these unit costs increase at least 25 percent over the current baseline estimate or at least 50 percent over the original, DOD is required to take additional steps, including conducting an in-depth review of the program. Programs with critical breaches must be terminated unless the Secretary of Defense certifies to certain facts related to the programs and takes other actions, including restructuring the programs. 10 U.S.C. § 2433a.

Table 1: Planned F-35 Joint Strike Fighter Program Cost and Quantity, 2001–2017

	October 2001 initial baseline	March 2012 baseline	Difference from 2001 to 2012	December 2017 estimate	Difference from 2012 to 2017
Expected number of aircraft					
Developmental aircraft	14	14	0	14	0
Procurement aircraft	2,852	2,443	-409	2,456	13
Total aircraft	**2,866**	**2,457**	**-409**	**2,470**	**13**
Estimated delivery and production dates					
Initial operational capability	2010–2012	Undetermined[a]	Undetermined[a]	2015–2018	5–6 years[b]
Full-rate production	2012	2019	7 years	2019	0 years
Cost estimates (dollars in billions)[c]					
Development	34.4	55.2	20.8	55.5	0.3
Procurement	196.6	335.7	139.1	345.4	9.7
Military construction	2.0	4.8	2.8	5.3	0.5
Total program acquisition	**233.0**	**395.7**	**162.7**	**406.1**	**10.5**
Unit cost estimates (dollars in millions)[c]					
Program acquisition	81	161	80	164.4	3.4
Average procurement	69	137	68	140.6	3.6

Source: GAO analysis of Department of Defense (DOD) data. | GAO-18-321

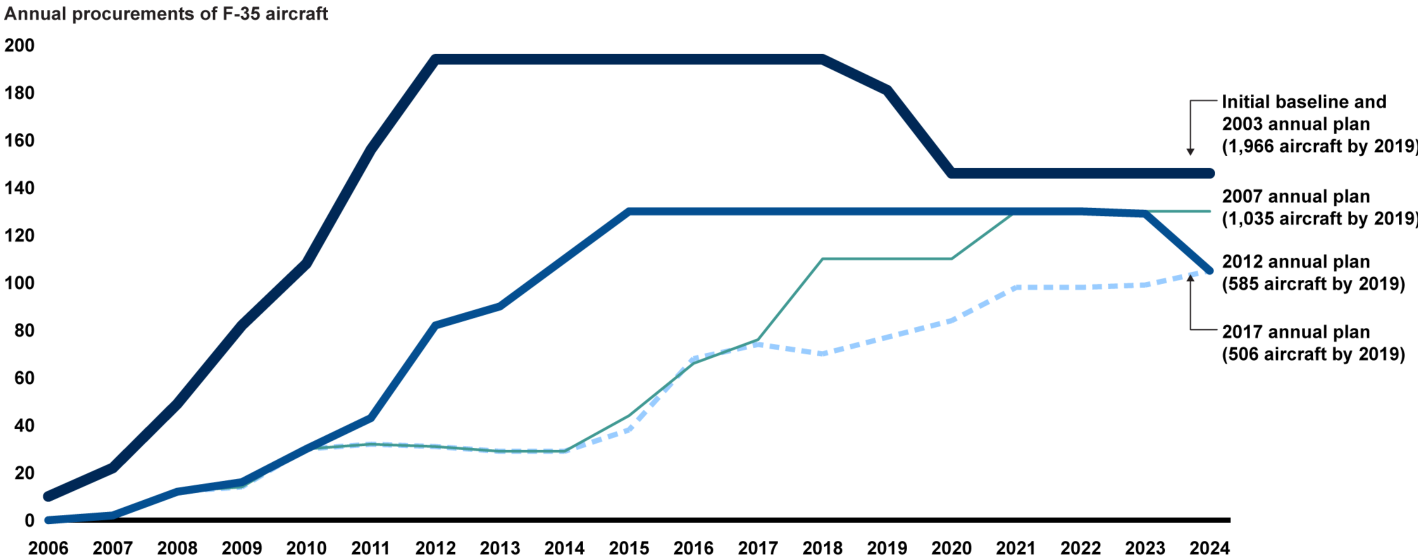
[a]When the baseline was finalized, DOD had not yet identified new initial operational capability dates for the military services. Amounts may not sum due to rounding.

[b]This is the difference from the October 2001 baseline to the December 2016 estimate.

[c]Annual projected cost estimates expressed in then-year dollars reflect inflation assumptions made by a program.

With each restructuring, DOD has reduced its near-term aircraft procurement quantities. Between 2001 and 2007, and between 2007 and 2012, DOD deferred the production of 931 and 450 aircraft, respectively. Over the past year, DOD has reduced near-term quantities again due to delays in development, postponing the procurement of 6 additional aircraft. As a result, the program will now end production in 2044 instead of 2038 as previously planned. Additionally, although the original “ramp-up” to the program’s largest annual procurements was planned to occur in 2012, as shown by the bold top line in figure 1 below, the program office now expects to reach this point for U.S. aircraft in 2024.

Figure 1: The F-35 Joint Strike Fighter Reduced Near-Term Procurements over the Past Year and Since Previous Plans



Source: GAO analysis of Department of Defense data. | GAO-18-321

Though the program's cost has increased significantly since 2001, the program office reported it has met all nine of its capability thresholds—or the minimum acceptable value for each capability—and has delivered three of those nine key capabilities.[6] By 2019, DOD expects to complete developmental and operational testing to determine whether all the capabilities will be delivered.

As the F-35 program delivers capabilities and transitions from development to production and sustainment—the operations and support phase of the acquisition—in 2019, it is working to improve the aircraft's reliability and maintainability. Reliability is the probability that a system will be able to perform a required function under certain conditions, and maintainability is the ability to maintain the system to a specific condition.

DOD is planning to add new capabilities to the F-35 aircraft to address evolving threats in its follow-on modernization program. We reported in

[6]The F-35's nine capabilities are force protection, net ready, radar frequency signature, combat radius, mission reliability, logistics footprint, sortie generation rates, F-35C recovery performance, and F-35B mission performance.

August 2017 that the program has experienced delays in starting this effort.[7]

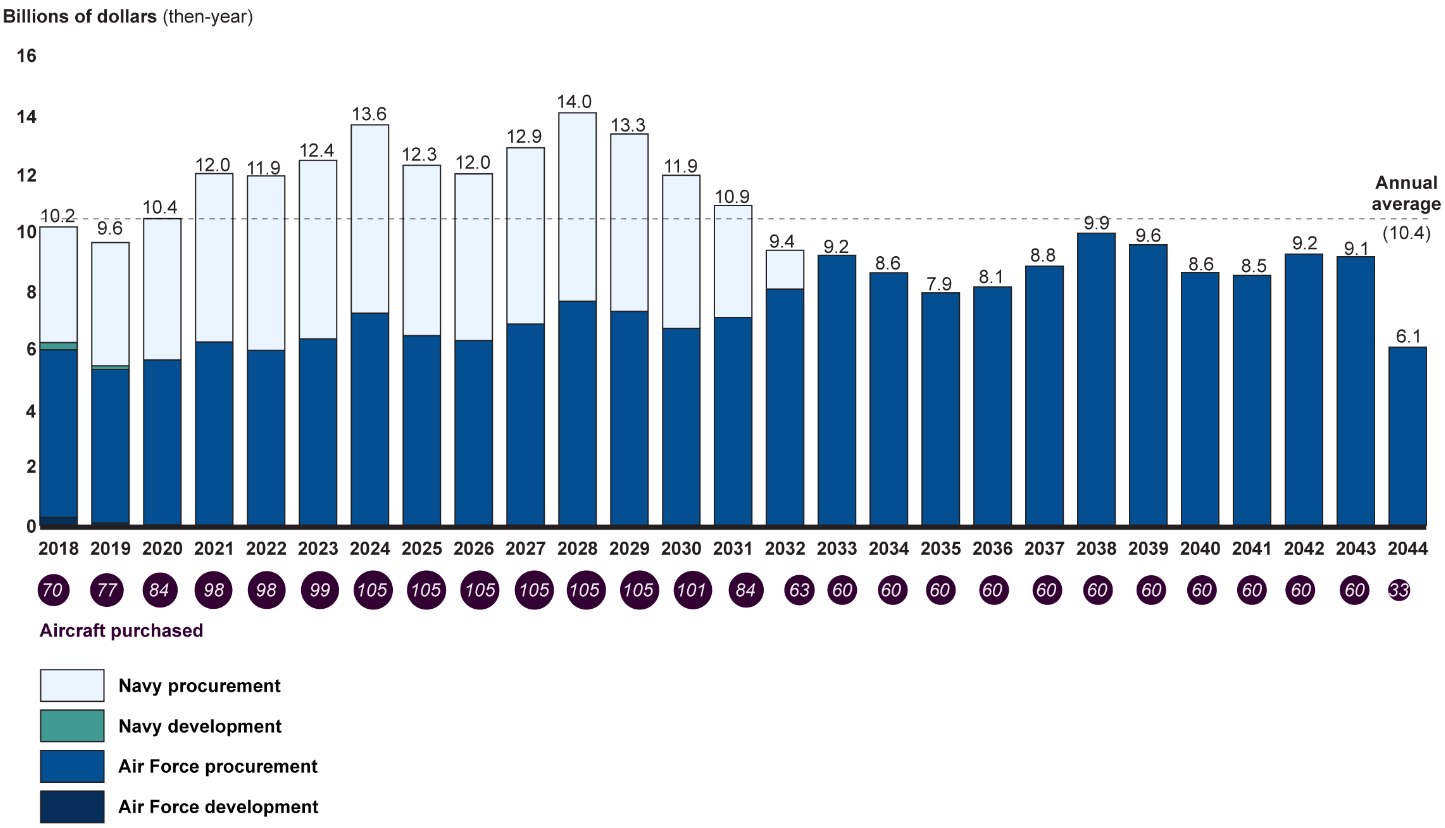
The F-35 Program Faces Affordability Challenges

The F-35's current estimated acquisition cost—which includes development and procurement funding—is over $406 billion, making it, by far, DOD's most costly acquisition program. While DOD is taking a number of actions to mitigate affordability concerns with the F-35 program, it remains a challenge for the military services and our international partners moving forward.

The program is approaching its full-rate production decision in 2019 and plans to reach peak production in 2024, spending more than $10.4 billion a year on average through 2044 (see fig. 2).

[7]GAO, *F-35 Joint Strike Fighter: DOD's Proposed Follow-on Modernization Acquisition Strategy Reflects an Incremental Approach Although Plans Are Not Yet Finalized*, GAO-17-690R (Washington, D.C.: Aug. 8, 2017).

Figure 2: F-35 Joint Strike Fighter Estimated Development and Procurement Costs



Source: GAO analysis of Department of Defense data. | GAO-18-321

Note: While this figure includes funding from the U.S. military services, our international partners, and our foreign military sales customers, it only depicts the number of aircraft purchased by the U.S. military services.

Over the past 10 years, the F-35 program has procured aircraft and conducted developmental flight testing at the same time.[8] As a result, the 213 aircraft that the program has already procured and delivered will need retrofits to fix issues found during testing. As the program approaches its full-rate production decision, planned for October 2019, the number of aircraft it procures each year will increase until 2024. Concurrency costs—the costs of retrofitting delivered aircraft—may also

[8]Developmental testing is intended to provide feedback on the progress of a system's design process and its combat capability as it advances toward initial production or deployment.

change. The program's total estimated cost of concurrency stands at $1.4 billion, the lowest it has been since 2012.[9] The program office estimates that over 501 aircraft will be procured by the time initial operational test and evaluation is completed.[10]

The military services will also incur substantial sustainment costs once they acquire the F-35 aircraft. In October 2017, we found that DOD did not have insight into the program's total sustainment costs, estimated at over $1.1 trillion over a 60-year life cycle.[11] As a result, we recommended that DOD revise its F-35 sustainment plans to ensure that it has sufficient knowledge of costs.[12] Since then, the program office has created a working group to analyze actual sustainment costs and to incorporate them more quickly into the program's cost estimates.

Given these significant acquisition and sustainment costs, DOD will likely face affordability challenges as it prioritizes the funding needs of the F-35 program with other large acquisition programs, such as the Air Force's B-21 bomber and KC-46A tanker and the Navy's *Columbia*-class ballistic missile submarine, among others. As a result, the Air Force, Marine Corps, and Navy are examining how they can afford their planned annual procurement quantities within their current budgets. According to an Air Force official, the service may have to reduce its total planned procurement quantities to afford the estimated sustainment costs needed to keep the aircraft in operational readiness. Meanwhile, Navy officials are conducting an affordability analysis on its F-35Cs, to be completed in 2018.

To improve its affordability, the F-35 program office is investing in projects—such as the Blueprint for Affordability initiatives—to lower production and sustainment costs and is pursuing economic order quantity purchases.

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[9]This estimate includes deficiencies that may still be identified in operational testing.

[10]Operational testing is intended to evaluate a system's effectiveness and suitability under realistic combat conditions before full-rate production or deployment occurs.

[11]GAO, *F-35 Aircraft Sustainment: DOD Needs to Address Challenges Affecting Readiness and Cost Transparency*, GAO-18-75 (Washington, D.C.: Oct. 26, 2017).

[12]GAO-18-75.

- The program office has invested $230 million in its Blueprint for Affordability initiatives. It is now evaluating initiatives identified by Lockheed Martin and its subcontractors in which it expects to invest an additional $110 million. The program office estimates that these initiatives could result in up to $8 billion in savings over the life of the program. These initiatives include efforts to improve manufacturing processes.
- The program office awarded a contract that it plans to use for future economic order quantity purchases, but potential future savings have not been determined. The program office's economic order quantity approach involves making large purchases of components that will be used across multiple procurement lots of aircraft. The approach is intended to reduce costs by buying components in bulk and achieving economies of scale.

In November 2017, DOD initiated an F-35 cost analysis to improve the F-35's affordability. Specifically, over the next year, the Director of Defense Pricing will conduct a detailed review of the cost to produce the F-35, which is intended to inform the negotiations for future contracts, according to the Director of Defense Pricing. The Director plans to report on the results from this effort in late summer 2018.

The F-35 Program Plans to Complete Development and Move to Full-Rate Production before All Deficiencies Have Been Resolved

In 2017, the program office made progress in completing developmental testing and completed that testing in April 2018. The program office plans to start its initial operational test and evaluation once enough test aircraft have been updated to the final production configuration. However, the program will defer action on some deficiencies found during developmental testing until after entering full-rate production, which could contribute to additional program costs.

The F-35 Development Program Is Nearly Complete

The F-35 development program completed developmental testing in April 2018, about 6 months later than the program office had planned last year. We and the DOD Director of Operational Test and Evaluation (DOT&E) had previously reported concerns that completion of testing in October

2017, as the program office planned, was unrealistic, primarily due to the rate at which the program completed test points in the past.[13]

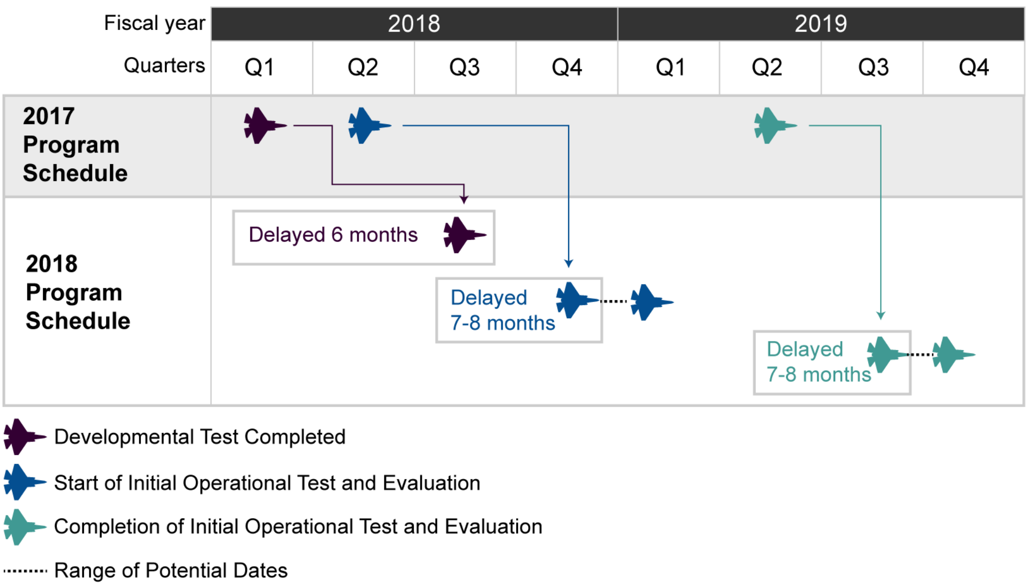
According to program officials, the program had about 8,300 test points to complete in January 2017 and, as of December 2017, about 800 remained. In 2017, the program office identified and removed about 2,500 of the remaining test points that it considered redundant, in part to reduce the amount of work and time needed to complete the developmental test program. According to program officials, removing test points is typical for every major weapon system as it nears the end of developmental testing. While DOT&E officials do not have a decision-making role in this process, they reported concerns to the program office that reducing test points adds risk of discovering new issues during operational testing that otherwise would have been identified through more robust developmental testing. At the same time, the program office added 1,179 test points, as of September 2017. While the program continued to reduce the overall number of test points, the trend of high test-point growth we identified last year persisted, contributing to developmental testing delays.[14]

Initial operational test and evaluation is now planned to start in September or October 2018—once enough test aircraft are upgraded to the final production configuration—and finish between June and September 2019, according to program officials. The program has delayed the start of operational testing by about 7 months due to persistent delays in developmental testing and to upgrade test aircraft. The schedule changes to developmental and operational testing from 2017 through 2018 are shown in figure 3.

[13]Test points are specific, quantifiable objectives in flight plans that are needed to verify aircraft design and performance. GAO-17-351.

[14]GAO-17-351.

Figure 3: F-35 Joint Strike Fighter Testing Schedule Is Delayed



Source: GAO analysis of Department of Defense data. | GAO-18-321

To mitigate further potential schedule delays, the program office, in coordination with DOT&E, has received conditional approval from DOT&E to conduct some preoperational testing activities as early as January 2018, before the official start of initial operational test and evaluation.

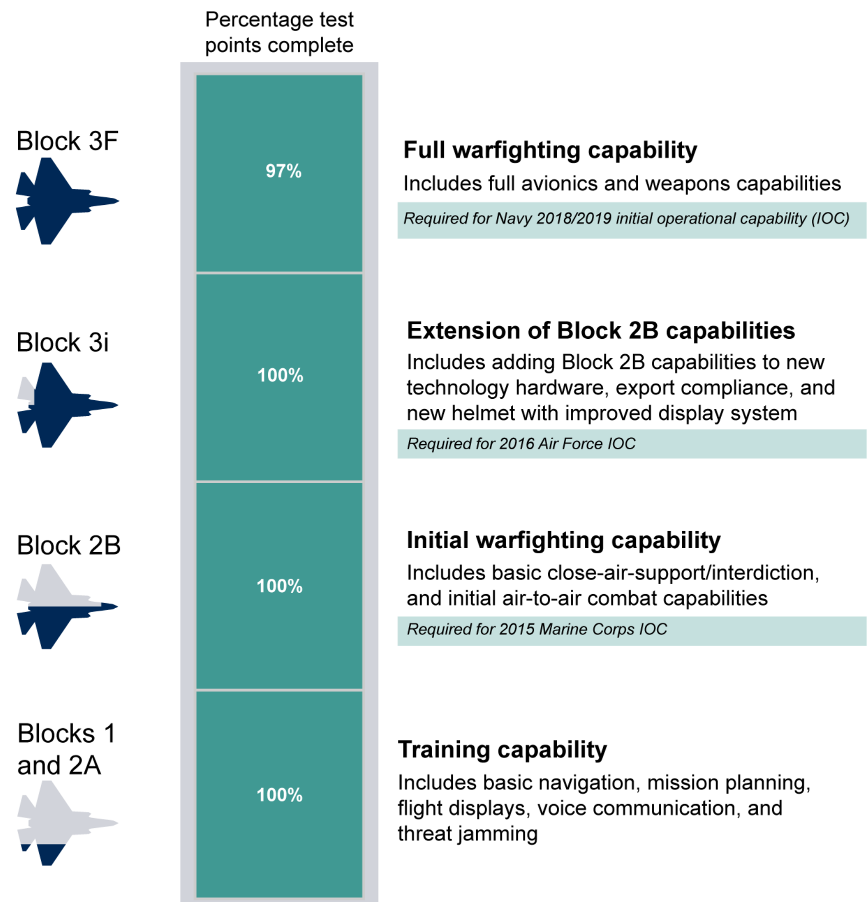
According to DOT&E officials, although the pre-operational testing may allow the program to complete some testing before the formal start of operational testing this fall, there is still a risk of further delays if new deficiencies are discovered. Delays in initial operational testing would affect two other upcoming program decisions: (1) the Navy's decision to declare initial operational capability (IOC) for its F-35C variant, scheduled between August 2018 and February 2019 and (2) DOD's decision to begin full-rate production in October 2019.

The program is fielding F-35 mission systems capabilities in software blocks: (1) Block 1, (2) Block 2A, (3) Block 2B, (4) Block 3i, and (5) Block 3F.[15] Generally, each subsequent block builds on the capabilities of the preceding block. Blocks 1 through 3i are now complete, and the program

[15]Block 3i configuration was a re-hosting of Block 2B capabilities on newer processors.

is currently focused on testing and fielding Block 3F. Lockheed Martin completed the coding of software capabilities for Block 3F—the final configuration for each variant in the development program—and delivered them to the test fleet to validate the capabilities for the completion of developmental testing. As of February 2018, 97 percent of Block 3F capabilities testing was complete. Figure 4 illustrates the mission systems software blocks being developed for the program, the percentage of test points completed by block, and the build-up to full warfighting capability with Block 3F.

Figure 4: Capabilities of the F-35 Joint Strike Fighter Mission Systems Software Blocks as of February 2018



Source: GAO analysis of Department of Defense data. | GAO-18-321

Program office officials stated that they implemented new software development processes, which contributed to greater testing efficiency. In 2017, we reported that mission systems software stability events—the unexpected shutting down and restarting of software—was a primary factor contributing to delayed completion of developmental testing.[16] In 2017, however, developmental test officials told us that many stability events are now resolved so quickly that they are unnoticeable to the pilot. According to Lockheed Martin data, the number of hours between stability events has improved over the past year. Program officials attributed improvements in software testing to the following:

- Greater communication between software engineers and test pilots. This enabled pilots to describe functionality concerns directly to the engineers who developed a particular capability. Engineers can now receive rapid feedback and incorporate fixes more quickly.
- Reducing the scope of software updates. By delivering smaller, issue-specific software updates, the program office increased the pace of testing. These smaller updates did not impact safety of flight, and therefore did not require an extensive and time-consuming validation process before they can be used in flight. This allowed the program to rapidly test new improvements.

Some Deficiencies Will Not Be Resolved before Full-Rate Production

To complete the F-35 development program without further delays, the program office plans to defer resolving—to fix or have an approved work around—a portion of the known deficiencies to post-development efforts. During testing, issues identified with the aircraft's performance are reported to the program office as deficiencies, which are then categorized based on how severely the deficiency impacts the aircraft's performance.

- Category 1 deficiencies are those that could jeopardize safety, security, or another critical requirement.
- Category 2 deficiencies are those that could impede or constrain successful mission accomplishment.

According to program office officials, in early 2017 the program office determined that not all open deficiencies found in developmental testing could be resolved within the cost and schedule of the development contract. As a result, the program office and the military services

[16] GAO-17-351.

reviewed all open deficiencies and determined that about 30 percent of them needed to be resolved before completing development. According to program officials, some of the remaining deficiencies will be resolved through post-development contracts and not on the baseline development contract.

While the program office's plans for resolving deficiencies remain in flux, officials told us that some are expected to be resolved on future contracts and not through the existing development contract. DOD officials have stated that the program will hold a summit later this year to determine who will be responsible for the costs associated with resolving the remaining deficiencies.

As of January 2018, the F-35 program had 966 open deficiencies—111 category 1 and 855 category 2. At least 25 category 1 deficiencies and 165 category 2 deficiencies will not be resolved before full-rate production. See table 2 for a breakdown of deferred category 1 deficiencies by the system affected. Key technical risks are described in appendix III.

Table 2: F-35 Category 1 Deficiencies Planned for Resolution after Full-Rate Production

Affected system	Number of deficiencies
Air Vehicle	6
Avionics	12
Weapons	4
Software	2
Propulsion	1
Total	**25**

Source: Department of Defense. | GAO-18-321

According to program officials, it is time to complete the development program as all capabilities have met threshold requirements and are on track to be delivered. Therefore, they told us that it is reasonable to continue resolving deficiencies while in production. The program officials stated that the proposed approach for resolving deficiencies is still under consideration and has not been approved.

DOD's acquisition instruction, however, states that critical deficiencies identified in testing are to be resolved before proceeding beyond low-rate

initial production or limited deployment, except as specifically approved by the program's milestone decision authority.[17] This policy states that identifying and correcting deficiencies early is less costly than resolving deficiencies later in the acquisition process. If the critical deficiencies are not resolved before moving to production, the F-35 program faces additional concurrency costs to fix fielded aircraft—which are currently estimated at $1.4 billion.

F-35 Reliability and Maintainability Targets Are Unlikely to Be Met before Reaching Maturity

The F-35 program office saw little improvement in reliability and maintainability over the past year. We found that the program may not meet its required targets in these areas before each variant is expected to demonstrate maturity—the point at which the aircraft has flown enough hours to predictably determine reliability and maintainability over its lifespan. Each variant is measured against eight metrics; four reliability and maintainability metrics are near targets, but the other four continue to fall short. While the program office has an improvement program and has completed some reliability and maintainability improvement projects, this effort does not address what actions are needed to meet all of its targets.

The F-35 Program Is Meeting, or Close to Meeting, Four of Its Eight Reliability and Maintainability Targets

The program office is performing near or above targets for four of its reliability and maintainability metrics, demonstrating little change from its overall performance last year, as shown in table 3 below.

[17] Department of Defense Instruction 5000.02, *Operation of the Defense Acquisition System* (Jan. 7, 2015, incorporating change 3, Aug. 10, 2017).

Table 3: F-35 Program Performance Compared to Reliability and Maintainability Metrics, as of August 2017

Metric[a]	F-35A	F-35B	F-35C
Mission Reliability[b]—measures the probability of successfully completing a mission of average duration	●	●	●
Mean flight hours between failure (design controlled)—measures time between failures that are directly attributable to the design of the aircraft and are considered fixable with design changes	●	◓	●
Mean time to repair—measures the amount of time it takes a maintainer to repair a failed component or device	◓	◓	●
Maintenance man hours per flight hour—measures the average amount of time spent on scheduled and unscheduled maintenance per flight hour	●	◓	●
Mean flight hours between maintenance event—also referred to as the logistics reliability metric, measures time between maintenance, unscheduled inspections, and servicing actions, including consumables[c]	○	○	○
Mean flight hours between removal—measures the time between part removals from the aircraft for replacement from the supply chain	○	○	○
Mean flight hours between critical failure—measures the time between failures that result in the loss of a capability to perform a mission-critical capability	○	○	○
Mean corrective maintenance time for critical failures—measures the amount of time it takes to correct critical failure events	○	○	○

Legend:

●: Metric is near or above current targets
◓: Metric is near or above minimum targets
○: Metric is below targets

Source: F-35 program office assessment of contractor data. | GAO-18-321

[a]Each metric is measured using a 3-month average and reported on a monthly basis; this table summarizes the Joint Reliability and Maintainability Evaluation Team's review of reliability growth and maintainability improvement data from November 2009 through August 2017.

[b]Mission Reliability is a key performance parameter. It, as well as all of these metrics, will be evaluated during initial operational test and evaluation.

[c]Consumable parts are nonrepairable items or repair parts that can be discarded more economically than they can be repaired or that are consumed in use (such as oil filters, screws, nuts, and bolts).

The F-35 operational requirements document—the document that outlines the requirements DOD and the military services agreed the F-35

should meet—provides performance targets for all of these metrics at the time each variant reaches maturity—when all variants have flown a combined 200,000 hours. However, similar to our findings, DOT&E reported in January 2018 that each variant's reliability growth remained stagnant over the last year and that it is unlikely the program will achieve targets for most of these metrics by maturity.[18]

As of August 2017, the F-35 test and operational fleet had flown a total of almost 95,000 flight hours, or almost half of the 200,000 hours needed for all variants to reach maturity. So far, the F-35A is closest to full maturity, having flown over 54,000 of its 75,000 hours needed to reach maturity, which it is expected to achieve in mid-2018. Because it is the closest to maturity, it is therefore the most at risk of not achieving its reliability and maintainability targets. The F-35B and F-35C are less mature and will need to fly approximately 46,000 and 38,000 hours, by 2021 and 2024, respectively, to reach maturity, so there is more time for those metrics to improve.

The F-35 Program Office Does Not Have a Plan to Ensure All Reliability and Maintainability Targets Will Be Met by Full Aircraft Maturity

The program office has a program that is intended to improve the F-35's reliability and maintainability metrics, but it has not addressed what steps are needed to ensure they meet targets. Under DOD's instruction for systems acquisition, program managers are to formulate a comprehensive reliability program using an appropriate strategy to ensure reliability requirements are achieved.[19] Demonstrating the reliability of a system before full-rate production is an acquisition best practice identified by GAO, as it indicates the design is stable and minimizes manufacturing risk.[20] In addition, it helps ensure that the manufactured aircraft do not have to undergo further costly retrofits to fix reliability and maintainability problems.

The program has a Reliability and Maintainability Improvement Program and has invested $21 million to date on past and continuing reliability improvements. However, this program does not address whether these

[18]Director, Operational Test & Evaluation, *Fiscal Year 2017 Annual Report* (January 2018).

[19]Department of Defense Instruction 5000.02, *Operation of the Defense Acquisition System*.

[20]GAO, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: July 15, 2002).

improvements will be sufficient to close the gap for the four metrics not currently meeting targets, as indicated in table 3 above. In fact, the plan only mentions three key reliability and maintainability metrics—the mean flight hours between failure, mean time to repair, and maintenance man hours per flight hour. It is unclear how the improvement program's strategies would improve the metrics that are not mentioned, including those not meeting targets, prior to each variant's planned maturity.

The F-35 development contract specifications contain performance requirements that include the four reliability and maintainability metrics against which the program is performing well. The four metrics in which the program is not performing well are not in the contract specifications, but are in in the operational requirements document. As a result, the program office is focused on ensuring the contractor meets its contractual requirements for reliability and maintainability but not on the other four metrics required in the operational requirements document. If the requirements in the operational requirements document are not met, sustainment costs for the military services could be higher than currently budgeted.

Absent an assessment of the actions needed to improve the reliability and maintainability metrics and a plan to make all necessary improvements, the program is not likely to meet reliability and maintainability targets for the four underperforming metrics. Without renewed emphasis on achieving the reliability and maintainability targets by maturity, the Air Force, Navy, and Marine Corps will have to decide whether they are willing to accept less reliable and maintainable aircraft than originally planned. Among other outcomes, this may mean taxpayers would have to pay more down the road to fix problems as well as potentially taking aircraft out of operations for more maintenance than anticipated.

Manufacturing Continues to Gain Efficiencies

Both the F-35 airframe and engine contractors continue to report improvements to manufacturing processes. Figure 5 shows an image of the Lockheed Martin production line.

Figure 5: An F-35 in the Production Process



Source: Lockheed Martin. | GAO-18-321

Since 2012, the airframe manufacturer—Lockheed Martin—has improved manufacturing efficiency, reflecting a positive trend since the program's restructuring. Table 4 shows improvements in Lockheed Martin's production metrics since 2012 and over the past year.

Table 4: F-35 Airframe 2012, 2016, and 2017 Deliveries and Labor Hours Have Generally Improved

Metric	2012	2016	2017
Total aircraft delivered	**29**	**46**	**66**
Average labor hours per F-35A delivered	108,355	47,269	41,541
Average labor hours per F-35B delivered	107,998	61,928	57,152
Average labor hours per F-35C delivered	_[a]	65,187	60,121
Average total hours for scrap, rework, and repair per aircraft delivered	20,125	7,797	6,237

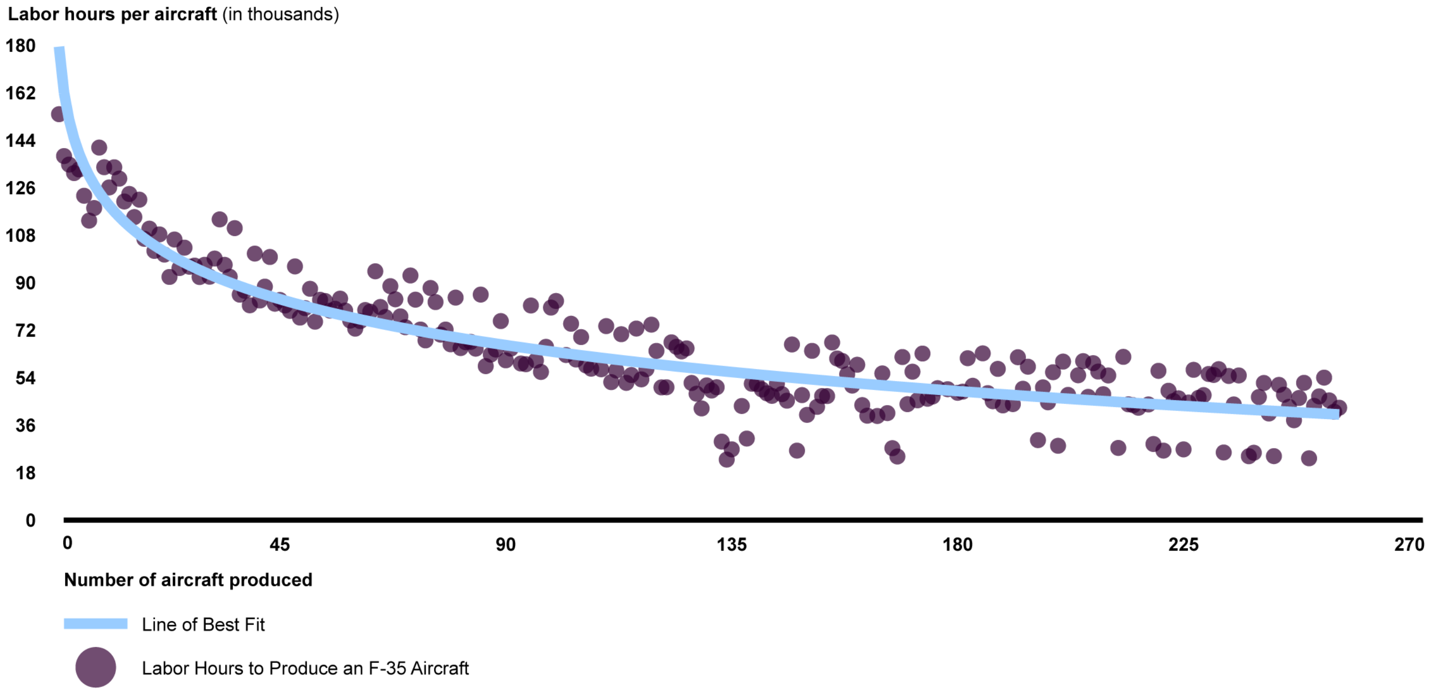
Source: Lockheed Martin. | GAO-18-321

[a]No airframes were delivered in 2012

These improvements in airframe manufacturing efficiency indicate that manufacturing processes are stabilizing and coming under control, and

production capability is improving. Lockheed Martin has delivered a total of 266 aircraft to DOD and international partners. As of January 2018, 170 aircraft were in production worldwide, an increase of 20 percent from January 2017.[21] As Lockheed Martin gained more production experience, the average hours needed to produce an aircraft decreased, as shown in figure 6. The line of best fit, shown below, is calculated to help visualize a trend in the rate of change in the data.

Figure 6: F-35 Joint Strike Fighter Declining Labor Hours per Aircraft Delivered



Source: GAO analysis of Department of Defense data. | GAO-18-321

The hours of work done out of the proper production sequence per aircraft are also decreasing, as earlier problems with late deliveries of radar components from Northrop Grumman and a supplier's deficient

[21]Of the 266 aircraft delivered, 213 have been delivered to the United States and 53 have been delivered to international partners, including 14 to the United Kingdom, 2 to the Netherlands, 10 to Norway, 10 to Italy, 2 to Australia, 9 to Israel, and 6 to Japan. Of the 170 aircraft currently in production, 157 are for the United States and 13 are for international partners and foreign military sales.

coolant tube insulation are being resolved, which were issues we reported on last year.[22]

According to Lockheed Martin, the rate of quality defects discovered per aircraft delivered has declined 21 percent from 2016 to 2017. However, this metric will likely be affected next year due to a recent discovery of a fault in the production process. Specifically, according to Defense Contract Management Agency officials, in September 2017 Lockheed Martin halted deliveries of aircraft after the Air Force identified corrosion between the aircraft's surface panels and the airframe because Lockheed Martin did not apply primer when the panels were attached. According to the program office, the Defense Contract Management Agency, Lockheed Martin, and program office subject matter experts are investigating the impact on aircraft that have been delivered without the primer, and estimate that repairs may take between 30 to 40 days per aircraft at a cost that is yet to be determined. More than 270 aircraft have been identified as lacking the necessary primer as of February 2018. According to the program office, responsibility for the costs associated with this issue has not been negotiated. Meanwhile, delivery of aircraft resumed in October 2017.

In addition to the issue with the primer, according to Lockheed Martin supplier performance has been mixed. For example:

- Suppliers delivered 97 percent of parts on time in 2017; this is up from almost 94 percent in 2016.
- Out of all of Lockheed Martin's suppliers, 9 percent improved their quality of delivered components.
- Eight percent of suppliers' quality of delivered components declined. Lockheed Martin representatives told us that they have implemented corrective action plans for these suppliers.

Over the past year, Pratt & Whitney—the engine manufacturer—has shown similar improvements in manufacturing efficiency. According to Pratt & Whitney, its annual production rate increased by 12 percent, with 73 engines delivered from January to mid-December 2017. The F-35A and F-35C engine cost has declined by $4.2 million dollars from the initial production lot in 2007 to the 10th lot in 2017. Table 5 shows improving trends in engine deliveries and labor hours.

[22]GAO-17-351.

Table 5: F-35 Engine 2012, 2016, and 2017 Deliveries and Labor Hours Have Generally Improved

Metric	2012	2016	2017
Total engines under contract	**35**	**60**	**73**
Total engines delivered	**48**	**65**	**73**
Average labor hours	1,555	1,239	1,272
Average percentage of labor hours for scrap, rework, and repair	2.4	3.2	2.0

Source: Department of Defense and Pratt & Whitney. | GAO-18-321

In 2017, Pratt & Whitney made progress in other areas of its engine production. For example, it set up the first engine testing system at the new final assembly center in Japan, which delivered its first engine in November 2017. In addition, as the company's production experience has increased, the number of quality issues discovered declined in 6 of the 8 years of production. However, according to Defense Contract Management Agency officials, Pratt & Whitney is not expected to reach its spare-parts delivery requirements until mid-2018 due to limited production capacity at a key supplier. Pratt & Whitney is working with some suppliers to improve product quality and is completing a review of its production process to prepare for increased production rates over the next 5 years.

According to representatives of both contractors, they are taking steps to increase their annual production rates and plan to produce 70 aircraft for DOD in 2018 and achieve full-rate production in October 2019, producing 77 aircraft that year. Both contractors are hiring and training more staff, adding production capacity and tooling, and working with their suppliers to help ensure increased and on-time deliveries, according to Lockheed Martin.

DOD Has Delayed F-35 Modernization and Has Requested Funding before Establishing Its Business Case

Due to evolving threats, DOD plans to add new capabilities and modernize the F-35 in an effort it refers to as Block 4. Over the past year, DOD has been reevaluating its approach to implementing Block 4, to deliver capabilities more frequently to the warfighter. DOD expects to update its acquisition strategy for Block 4 in June 2018 and award a development contract 1 year later.

In April 2017, we found that Block 4 was expected to be developed and delivered in four phases—which DOD referred to as 4.1, 4.2, 4.3, and 4.4.[23] In August 2017, we found that DOD estimated Block 4 would cost $3.9 billion through 2022.[24] This cost estimate exceeded the thresholds for what constitutes a major defense acquisition program.[25] In fact, in April 2016, we recommended that DOD make the Block 4 modernization a separate program, with its own baseline and regular cost, schedule, and performance reporting.[26] In April 2017, we also found that delays in developmental testing in the baseline program could affect the modernization requirements going forward.[27] Consequently, we recommended that the program delay Block 4 modernization efforts until developmental testing is complete and all associated capabilities are verified to work as intended.[28] DOD disagreed with both of our recommendations, citing the need for a seamless transition from the baseline program to the Block 4 modernization efforts. Since then, the program experienced delays in its baseline developmental testing. This year, the F-35 program office reassessed its approach for Block 4, which resulted in DOD delaying its Block 4 plans, as we had recommended. The program office is currently in transition between ending development and starting modernization, and over the next year it will be establishing a

[23]GAO-17-351.

[24]GAO-17-690R.

[25]Major defense acquisition programs are those either identified by DOD or in which the estimated eventual total expenditure for research, development, test, and evaluation is more than $480 million in fiscal year 2014 constant dollars or, for procurement, is more than $2.79 billion in fiscal year 2014 constant dollars. See U.S.C. § 2430; DOD Instruction 5000.02, *Operation of the Defense Acquisition System*.

[26]GAO-16-390.

[27]GAO-17-351.

[28]GAO-17-351.

program baseline for Block 4 and plans to provide Congress updates on it.

Section 224 of the National Defense Authorization Act for Fiscal Year 2017 required DOD to submit a report that contains certain elements of an acquisition program baseline—in essence, a full program business case—to Congress by March 31, 2017. The report was to include the cost, schedule, and performance information for Block 4.[29] In January 2018, DOD provided its report to Congress, outlining its preliminary plans for (1) the program's transition from development to the Block 4 modernization effort and (2) limited details on some elements of the Block 4 acquisition program baseline. It also identified a new approach for modernizing the F-35 over its life, referred to as Continuous Capability Development and Delivery (C2D2), in which capabilities are developed, tested, and delivered in parallel as they are matured and delivered. According to the report, this new methodology is intended to deliver capabilities more frequently to the warfighter by breaking Block 4 into smaller capability increments. As the approach is still in development, the report does not lay out DOD's full business case for Block 4, including its total cost, schedule, and performance plans for delivering new capabilities using the new C2D2 methodology. DOD notes in its report that it will develop the full acquisition program baseline over the next year and provide a complete report to Congress by March 2019.

DOD's report states that, to establish C2D2 processes and improve the Block 4 baseline estimate, it will accomplish the following over the next two years:

- complete design work on new data processors,
- establish laboratory and flight-test assets for modernization requirements verification,
- address deficiencies from developmental testing, and

[29]The National Defense Authorization Act for Fiscal Year 2017 required the Secretary of Defense to submit to the congressional defense committees a report that contains the basic elements of an acquisition program baseline for Block 4 Modernization including: cost estimates for development, production, and modification; projected key schedule dates, including dates for the completion of a capabilities development document, an independent cost estimate, an initial preliminary design review, a developmental contract award, and a critical design review; technical performance parameters; technology readiness levels; and annual funding profiles for development and procurement.

- conduct planning and systems engineering work for initial capabilities for Block 4.

In its report, DOD noted that, collectively, these actions will prepare it to transition to Block 4.

Certain aspects of DOD's revised modernization plans may provide benefits to the program. For example:

- The program office is delaying the award of the Block 4 development contract to June 2019. This delay will provide about 10 more months to wrap up the F-35 original development program and lay a more solid, knowledge-based foundation for modernization.
- DOD intends to use government-owned open systems architectures and acquire data rights and skilled staff to develop Block 4, which may offer significant repair and upgrade benefits as well as increased opportunities for competition that could translate to savings as the systems age.
- Using the new and innovative C2D2 methodology may potentially shorten time frames for delivering capabilities over a traditional acquisition approach.

Other aspects of the plan, however, may limit oversight into the program's cost, schedule, and planned activities. Specifically:

- DOD does not plan to make Block 4 a separate acquisition program because it considers the F-35 DOD's most closely managed system. This means that the F-35's Selected Acquisition Report—the annual report to Congress that includes details of a major weapon system's cost, schedule, and performance status—will not distinguish between the baseline program and Block 4. According to DOD's January 2018 report, however, each capability will be baselined separately in the program's future Block 4 annual reports to Congress. These reports are required by Section 224 of the National Defense Authorization Act for Fiscal Year 2017, and the first report is required no later than 1 year after the award of the development contract. We will review these future reports to Congress to determine what level of insight they provide into the program's cost, schedule, and performance goals. DOD's January report also states that DOD plans to provide Congress updates over the next year.
- The program does not plan to hold a milestone B decision, a critical point in an acquisition program leading to production and fielding,

because it doesn't consider Block 4 to be a separate acquisition program. However, the program office states that it will hold Defense Acquisition Board reviews to provide scrutiny from the Office of the Secretary of Defense and the military services prior to awarding any Block 4 development contracts.

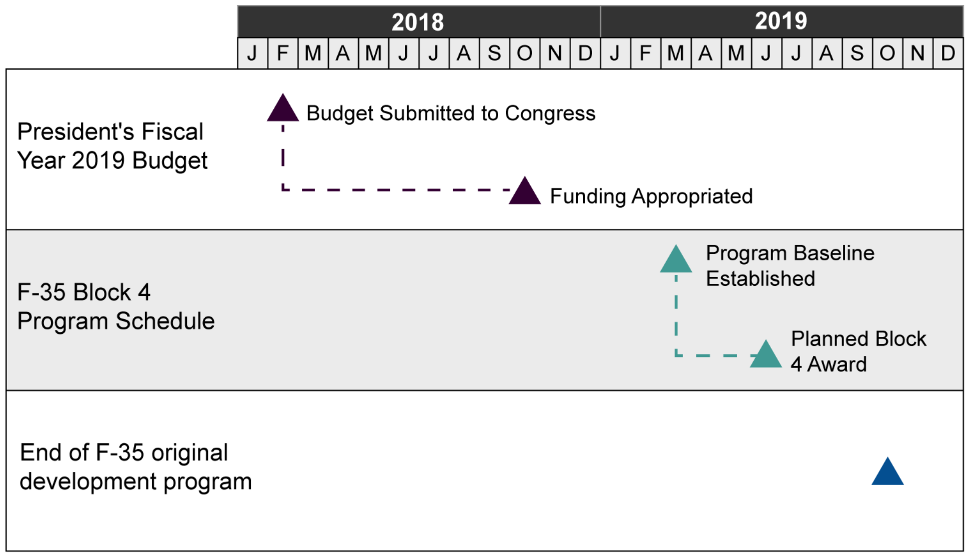
DOD's budget request for fiscal year 2019 included $278 million for development of Block 4 capabilities. According to the program office, a Defense Acquisition Board Review is scheduled in June 2018 to determine when a request for proposal will be issued for the Block 4 development. However, while this review will be informed by an updated acquisition strategy, it will not present the program's full business case for Block 4 until nearly a year later in March 2019. Major defense acquisition programs, generally follow DOD acquisition policy which states that prior to the release of a development contract request for proposals, there needs to be confidence that the program requirements are firm and clearly stated and the risk of committing to development has been or will be adequately reduced prior to contract award. Solid business cases should include, among other things, a complete acquisition program baseline, as well as

- an independent cost estimate,
- technology readiness assessments,
- a test and evaluation master plan,
- a system engineering plan,
- a preliminary design review, and
- an approved acquisition strategy.

According to DOD's January 2018 report, all of these will be finalized before DOD's next report in March 2019. As a result, DOD requested funding for modernization over a year before the program has a business case for Block 4, as shown in figure 7.[30]

[30]Since 2015, the program has contracted for three technology maturation and risk-reduction efforts—and plans to contract for a fourth—for new modernization capabilities prior to awarding its planned C2D2 development contract in 2019. Through fiscal year 2017, the U.S. and international partners have incurred $427 million for the predevelopment costs. According to program officials, these efforts are urgently needed in advance of the formal start of the modernization program to meet the military services' required timelines.

Figure 7: The F-35 Joint Strike Fighter Modernization's Upcoming Budgetary and Program Dates



Source: GAO analysis of Department of Defense data. | GAO-18-321

This means that the program is asking Congress to authorize and appropriate funds for Block 4 without insight into its complete cost, schedule, and technical baselines. Furthermore, once Congress appropriates these funds, DOD would be able to award a contract, beginning a long-term commitment to Block 4, the costs of which are not fully understood.

Conclusions

Over the past year, DOD has made progress in completing the F-35 development program. However, in its rush to cross the finish line, the program has made some decisions that are likely to affect aircraft performance and reliability and maintainability for years to come. Specifically, the program office plans to resolve a number of critical deficiencies after full-rate production. Resolving these deficiencies outside of the developmental program may contribute to additional concurrency costs, which also carries affordability implications.

Additionally, the program's reliability and maintainability metrics inform the program on the probability of failures and how much time the aircraft will be in maintenance. It stands to reason that less-reliable aircraft require more maintenance and parts than planned and might result in the

aircraft not being available for operations. If reliability targets are not met, the military services and the taxpayer will have to settle for aircraft that are less reliable, more costly, and take longer to maintain. Given that the program's long-term affordability is already in question, ensuring the aircraft is reliable by each variant's planned maturity is paramount.

Finally, since the program office has not yet established an acquisition program baseline—or a solid business case—for its modernization plans, pushing forward puts the program at risk of repeating mistakes from the original baseline F-35 development. The program office has requested funding for modernization before it has the requisite knowledge to match its proposed requirements to available resources. Such an approach would leave Congress without key information to make decisions regarding the allocation of resources. We continue to stand by our previous recommendation that the Secretary of Defense hold a milestone B review and manage F-35 modernization as a separate and distinct major defense acquisition program with its own acquisition program baseline and regular cost, schedule, and performance reports to the Congress. While DOD disagreed with this recommendation, stating that the F-35 is the most closely managed system within the department, implementing this recommendation could provide greater transparency and oversight.

Matter for Congressional Consideration

Congress should consider providing in future appropriations that no funds shall be available for obligation for F-35 Block 4 until DOD provides a report setting forth its complete acquisition program baseline for the Block 4 effort to the congressional defense committees. Such a report must reflect findings from

- an independent cost estimate,
- technology readiness assessments,
- a test and evaluation master plan,
- a system engineering plan,
- a preliminary design review, and
- an approved acquisition strategy.

Recommendations for Executive Action

We are making the following two recommendations to the Secretary of Defense:

Direct the F-35 program office to resolve all critical deficiencies before making a full-rate production decision. (Recommendation 1)

Direct the F-35 program office to identify what steps are needed to ensure the F-35 meets reliability and maintainability requirements before each variant reaches maturity and update the Reliability and Maintainability Improvement Program with these steps. (Recommendation 2)

Agency Comments and Our Evaluation

DOD concurred with both of our recommendations and provided us with technical comments which we incorporated as appropriate. DOD's comments are reprinted in appendix IV and summarized below.

DOD concurred with our first recommendation that the F-35 program office resolve all critical deficiencies before making a full-rate production decision. Initially, DOD did not concur with this recommendation because we recommended that critical deficiencies be fixed rather than resolved. DOD officials noted that the department's acquisition policy requires that critical deficiencies be resolved prior to proceeding beyond low rate initial production or limited deployment. According to DOD, resolving deficiencies affords the department with more flexibility to develop alternative solutions rather than technical fixes. Accordingly, we revised our recommendation. In concurring with the revised recommendation, DOD officials cited that they plan to resolve (i.e., fix, have an approved work-around, or formally accept) all of the F-35's critical deficiencies according to established processes applicable to all DOD acquisition programs prior to entering initial operational test and evaluation this fall. We will continue to monitor the program's progress on resolving deficiencies through operational testing, production, and modernization.

DOD concurred with our second recommendation and stated that it will work with the F-35 program office to update the Reliability and Maintainability Improvement Program with the steps needed to ensure continued progress towards the reliability and maintainability goals for each variant at maturity.

We are sending copies of this report to the appropriate congressional committees; the Secretary of Defense; and the Under Secretary of Defense for Acquisition and Sustainment, the Secretary of the Air Force, the Secretary of the Navy, and the Commandant of the Marine Corps. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or sullivanm@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.



Michael J. Sullivan
Director, Contracting and National Security Acquisitions

List of Committees

The Honorable John McCain
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Richard Shelby
Chairman
The Honorable Richard J. Durbin
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Mac Thornberry
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Kay Granger
Chairwoman
The Honorable Peter Visclosky
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Prior GAO Reports and DOD Actions

Table 6: Prior GAO Reports on the F-35 Joint Strike Fighter and Department of Defense (DOD) Responses

Year, GAO report	Estimated development costs, development length, and aircraft unit cost	Key program event	Primary GAO conclusions/ recommendations	DOD response and actions
2001 GAO-02-39	• $34.4 billion • 10 years • $69 million	Start of system development and demonstration approved.	Critical technologies needed for key aircraft performance elements are not mature. Program should delay start of system development until critical technologies are mature to acceptable levels.	DOD did not delay start of system development and demonstration, stating technologies were at acceptable maturity levels and that it will manage risks in development.
2005 GAO-05-271	• $44.8 billion • 12 years • $82 million	The program undergoes re-plan to address higher-than-expected design weight, which added $7 billion and 18 months to development schedule.	We recommended that the program reduce risks and establish executable business case that is knowledge-based with an evolutionary acquisition strategy.	DOD partially concurred but did not adjust strategy, believing that its approach was balanced between cost, schedule, and technical risk.
2006 GAO-06-356	• $45.7 billion • 12 years • $86 million	Program sets in motion plan to enter production in 2007 shortly after first flight of the non-production-representative aircraft.	The program was entering production with less than 1 percent of testing complete. We recommended that the program delay investing in production until flight testing shows that the Joint Strike Fighter performs as expected.	DOD partially concurred but did not delay start of production because it believed the risk level was appropriate.
2007 GAO-07-360	• $44.5 billion • 12 years • $104 million	Funding reduced for the first two low-rate production buys, thereby slowing the "ramp-up" of production.	Progress was being made, but concerns remained about undue overlap in testing and production. We recommended limiting annual production quantities to 24 a year until flying quantities were demonstrated.	DOD did not concur and stated that the program had an acceptable level of concurrency and an appropriate acquisition strategy.
2008 GAO-08-388	• $44.2 billion • 12 years • $104 million	DOD implemented a Mid-course Risk Reduction Plan to replenish management reserves from about $400 million to about $1 billion by reducing test resources.	We found that the new plan increased risks and recommended that DOD revise it to address concerns about testing, management reserves, and manufacturing. We determined that the cost estimate was not reliable and recommended a new cost estimate and schedule risk assessment.	DOD did not revise the risk plan or restore testing resources, stating that it will monitor the new plan and adjust it if necessary. Consistent with a report recommendation, a new cost estimate was prepared, but DOD did not conduct a risk and uncertainty analysis.

Year, GAO report	Estimated development costs, development length, and aircraft unit cost	Key program event	Primary GAO conclusions/ recommendations	DOD response and actions
2009 GAO-09-303	• $44.4 billion • 13 years • $104 million	The program increased the cost estimate and added a year to development but accelerated the production "ramp-up." An independent DOD cost estimate projected even higher costs and further delays.	We concluded that moving forward with an accelerated procurement plan and use of cost-reimbursement contracts was very risky. We recommended that the program report on the risks and mitigation strategy for this approach.	DOD agreed to report its contracting strategy and plans to Congress and conduct a schedule risk analysis. The program reported completing the first schedule risk assessment with plans to update semiannually. The department announced a major program change reducing procurement and moving to fixed-price contracts.
2010 GAO-10-382	• $49.3 billion • 15 years • $112 million	The program was restructured to reflect findings from a recent independent cost team and independent manufacturing review team. As a result, development funds increased, test aircraft were added, the schedule was extended, and the early production rate decreased.	Costs and schedule delays inhibited the program's ability to meet needs on time. We recommended that the program complete a comprehensive cost estimate and assess warfighter and initial operational capability requirements. We suggested that Congress require DOD to tie annual procurement requests to demonstrated progress.	DOD continued restructuring, increasing test resources, and lowering the production rate. Independent review teams evaluated aircraft and engine manufacturing processes. Cost increases later resulted in a Nunn-McCurdy breach. Military services are currently reviewing capability requirements, as we recommended.
2011 GAO-11-325	• $51.8 billion • 16 years • $133 million	Restructuring continued with additional development cost increases, and schedule growth; further reduction in near-term procurement quantities; and a decreased rate for future production. The Secretary of Defense placed the short takeoff and vertical landing variant (STOVL) on a 2-year probation, decoupled STOVL from the other variants, and reduced STOVL production plans for fiscal years 2011 to 2013.	We concluded that the restructuring actions were positive and, if implemented properly, should lead to more achievable and predictable outcomes. Concurrency of development, test, and production was substantial and provided risk to the program. We recommended that DOD maintain funding levels as budgeted; establish criteria for STOVL probation; and conduct an independent review of software development, integration, and test processes.	DOD concurred with all three of the recommendations. DOD lifted STOVL probation, citing improved performance. Subsequently, DOD further reduced procurement quantities, decreasing funding requirements through 2016. The initial independent software assessment began, and ongoing reviews were planned to continue through 2012.

Year, GAO report	Estimated development costs, development length, and aircraft unit cost	Key program event	Primary GAO conclusions/ recommendations	DOD response and actions
2012 GAO-12-437	• $55.2 billion • 18 years • $137 million	The program established a new acquisition program baseline and approved the continuation of system development, increasing costs for development and procurements and extending the period of planned procurements by 2 years.	Extensive restructuring placed the program on a more achievable course. Most of the program's instability continued to be concurrency of development, test, and production. We recommended that the Cost Assessment Program Evaluation office conduct an analysis of the impact of lower annual funding levels, and that the program office conduct an assessment of the supply chain and transportation network.	DOD partially concurred with conducting an analysis of the impact of lower annual funding levels and concurred with assessing the supply chain and transportation network.
2013 GAO-13-309	• $55.2 billion • 18 years • $137 million	The program continued to move forward following a new acquisition program baseline in 2012. In doing so, the program incorporated positive and more realistic restructuring actions taken since 2010, including more time and funding for development, and deferred procurement of more than 400 aircraft to future years.	The program was moving in the right direction but must fully validate design and operational performance and at the same time make the system affordable. We did not make recommendations to DOD in this report.	DOD agreed with GAO's observations.
2014 GAO-14-322	• $55.2 billion • 18 years • $135 million	The services established initial operational capabilities dates in 2013. The Marine Corps and Air Force are planning to field initial operational capabilities in 2015 and 2016, respectively, and the Navy plans to field its initial capability in 2018.	Delays in developmental flight testing of the F-35's critical software may hinder delivery of the warfighting capabilities to the military services. We recommended that DOD conduct an assessment of the specific capabilities that can be delivered and those that will not likely be delivered to each of the services by their established initial operational capability dates.	DOD concurred with our recommendation, and officials stated that they are in the process of conducting the assessment.

Year, GAO report	Estimated development costs, development length, and aircraft unit cost	Key program event	Primary GAO conclusions/ recommendations	DOD response and actions
2014 GAO-14-778	Not reported	DOD was developing several plans and analyses that will make up its overall F-35 sustainment strategy, which was expected to be complete in fiscal year 2019.	The annual F-35 operating and support costs were estimated to be considerably higher than the combined annual costs of several legacy aircraft. DOD had not fully addressed several issues that affect affordability and operational readiness. Operating and support cost estimates may not be fully reliable. GAO recommended that DOD develop better-informed affordability constraints; address three risks that could affect sustainment, affordability, and operational readiness; and take steps to improve the reliability of its cost estimates.	DOD concurred with all but one recommendation and partially concurred with the recommendation to conduct uncertainty analysis on one of its cost estimates, stating that it already conducts a form of uncertainty analysis.
2015 GAO-15-364	• $54.9 billion • 18 years • $136 million	Since the 2012 rebaselining, DOD has made changes to its F-35 procurement plans on an annual basis. The program also competed with other high-priority DOD programs for funding. In 2013 and 2014, DOD deferred a number of aircraft, extending the length of the program and increasing funding liability in the future.	The continuing changes in F-35 procurement plans indicate that the analysis done to support the program's 2012 baseline did not accurately account for future technical risks or funding realities. We recommended that DOD conduct an affordability analysis of the current procurement plan that reflects various assumptions about technical progress and funding availability.	DOD concurred with the recommendation and stated that it accomplishes an analysis of the program's current procurement plans with various assumptions about technical progress and funding availability every year as it conducts reviews for the budget process.
2016 GAO-16-390	• $55.1 billion • 18 years • $130.6 million	DOD planned to begin what it refers to as a block-buy contracting approach that was anticipated to provide cost savings. In addition, DOD planned to manage the follow-on modernization program under the current F-35 program baseline and not as its own separate major defense acquisition program.	The terms and conditions of the planned block buy and managing follow-on modernization under the current baseline could present oversight challenges for Congress. We recommended that the Secretary of Defense hold a milestone B review and manage follow-on modernization as a separate major defense acquisition program.	DOD did not concur with our recommendation. DOD viewed modernization as a continuation of the existing program and the existing oversight mechanisms, including regularly scheduled high-level acquisition reviews, will be used to manage the effort.

Year, GAO report	Estimated development costs, development length, and aircraft unit cost	Key program event	Primary GAO conclusions/ recommendations	DOD response and actions
2016 GAO-16-439	Not reported	The Marine Corps declared initial operational capability in July 2015, while the Air Force and Navy plan to declare initial operational capability in 2016 and 2018, respectively.	F-35 pilots and maintainers identified potential functionality risks to the Autonomic Logistics Information System (ALIS), and DOD lacks a plan to address these risks as key milestone dates approach. We recommended, among other things, that DOD develop a plan to address ALIS risks.	DOD concurred with our recommendation to develop a plan to address ALIS risks, and work was under way that would form the foundation of the plan. In 2016, the Joint Program Office completed an ALIS Technical Roadmap identifying five key areas for ALIS modernization and sustainment. In addition, an ALIS Training Evaluation (ATE) Summary of Findings report was completed identifying 23 areas for improvement across the ALIS Training curricula. The top eight improvement areas are on track to be completed by the end of calendar year 2017 to align with the fielding of ALIS version 3.0.
2017 GAO-17-351	• $55.1 billion • 18 years • $130.6 million	The DOD F-35 program office was considering contracts for economic order quantity of 2 years' worth of aircraft parts followed by a separate annual contract for procurement of lot-12 aircraft with annual options for lot-13 and lot-14 aircraft. However, as of January 2017, contractors stated they were still negotiating the terms of this contract; therefore, the specific costs and benefits remained uncertain.	Program officials project that the program will only need $576.2 million in fiscal year 2018 to complete baseline development. At the same time, program officials expect that more than $1.2 billion could be needed to commit to Block 4 and economic order quantity in fiscal year 2018. GAO recommended DOD use historical data to reassess the cost of completing development of Block 3F, complete Block 3F testing before soliciting contractor proposals for Block 4 development, and identify for Congress the cost and benefits associated with procuring economic order quantities of parts.	DOD did not concur with the first two recommendations and partially concurred with the third while stating that it had finalized the details of DOD and contractor investments associated with an economic order quantity purchase and will brief Congress on the details, including costs and benefits of the finalized economic order quantity approach.

Year, GAO report	Estimated development costs, development length, and aircraft unit cost	Key program event	Primary GAO conclusions/ recommendations	DOD response and actions
2017 GAO-17-690R	$3.9 billion 5 years	Congress has mandated in the National Defense Authorization Act for Fiscal Year 2017 that the Secretary of Defense submit a report by the end of March 2017 containing the basic elements of an Acquisition Program Baseline for the F-35 Block 4 and also required that GAO review DOD's report.	DOD plans to take an incremental, knowledge-based approach that will develop capabilities in four increments. While DOD has broadly established an incremental, knowledge-based framework for its modernization acquisition strategy, DOD officials noted that they are reassessing key cost, schedule, and capability aspects of the approach. As a result, the start of follow-on modernization has been delayed.	DOD provided technical comments.
2017 GAO-18-75	Not Reported	DOD is facing sustainment challenges that are affecting warfighter readiness. These challenges are largely the result of sustainment plans that do not fully include key requirements or aligned (timely and sufficient) funding.	DOD is taking steps to address some challenges, but without more comprehensive plans and aligned funding, DOD risks being unable to fully leverage the F-35's capabilities and sustain a rapidly expanding fleet. GAO recommended, among other things, that DOD revise sustainment plans, reexamine metrics and ensure that it has sufficient knowledge of costs and technical characteristics before entering into performance-based contracts, and improve communication with the services about sustainment costs.	DOD concurred with these recommendations and identified actions that it would take in response

Source: GAO | GAO-18-321

Appendix II: Scope and Methodology

The National Defense Authorization Act for Fiscal Year 2015 included a provision for GAO to review the F-35 acquisition program annually until the program reaches full-rate production. This is the third report under that provision. In this report, we assess (1) affordability; (2) progress toward completion of development and testing of the baseline aircraft; (3) reliability; (4) manufacturing progress, including supply chain performance; and (5) DOD's plans for a follow-on modernization program.

To assess the F-35 program's affordability, we identified the program's cost estimates and discussed past, ongoing, and future initiatives the program has to reduce acquisition costs. To analyze the program's costs, schedule, and performance plans, we compared the actual progress in each area with the goals established in its 2012 baseline to identify any significant deviations, trends, cost drivers, and high-risk areas. We analyzed DOD's selected acquisition report and its fiscal year 2018 budget request and discussed cost and manufacturing efficiency initiatives, such as the economic order quantities approach, with contractor and program office officials to understand potential cost savings and plans.

To assess progress in the F-35 development program and testing, we reviewed and analyzed cost performance reports, test data and results, program briefings, and internal DOD program analyses. We interviewed officials from the program office and contractors—Lockheed Martin and Pratt & Whitney—on key aspects of F-35 development progress, including flight testing, achievements over the past year, and test discoveries. We also interviewed program management, the Director, Operational Test and Evaluation office, and program test pilots. We obtained and analyzed data on mission systems test-point execution, both planned and accomplished, from January 2017 through December 2017. We compared test progress against the total program requirements to determine the number of test points that were completed and remaining as of December 2017. To assess the reliability of the test and cost data, we reviewed the supporting documentation and discussed the development of the data with DOD officials instrumental in producing them.

We also collected Reliability, Availability, and Maintainability data from January 2017 through December 2017. We compared these data to program reliability objectives to identify trends in actual performance. We assessed the data by reviewing supporting documentation and interviewed program office officials tracking reliability metrics and knowledgeable DOD testing officials. We determined that the data were

sufficiently reliable for our purposes of determining whether the program will meet its targets.

To assess ongoing manufacturing and supply chain performance and the program's plans for "ramp-up" to full rate production, we collected and analyzed data related to aircraft delivery rates and production performance data from 2012 to December 2017. We reviewed data and briefings provided by the program office, Lockheed Martin, Pratt & Whitney, and the Defense Contract Management Agency in order to identify issues in manufacturing processes. We discussed reasons for delivery delays and plans for improvement with Lockheed Martin and Pratt & Whitney. We also collected and analyzed data related to aircraft quality through December 2017 and discussed steps taken to improve quality and deliveries with Lockheed Martin and Pratt & Whitney.

The National Defense Authorization Act for Fiscal Year 2017 required DOD to submit an acquisition program baseline report—in essence a full program business case—to Congress by March 2017 that included the modernization's cost, schedule, and performance plans. It also included a provision for GAO to review the report and offer a briefing to the congressional defense committees on our findings within 60 days. To assess the program's follow-on modernization plans, we reviewed DOD's elements of an acquisition program baseline included in its January 2018 report to Congress and program documentation, and interviewed agency officials. We compared DOD's baseline report with the National Defense Authorization Act for Fiscal Year 2017 reporting requirements, relevant DOD policies and statutes, and GAO best practices. We also reviewed the fiscal year 2018 budget request to identify costs associated with the effort.

We conducted this performance audit from June 2017 to June 2018 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix III: Status of F-35 Technical Risks

The F-35 program continues to address technical risks discovered in testing. The program has incorporated design changes that have mitigated technical risks that we highlighted in our 2017 report including problems with the arresting hook and F-35B bulkhead cracks.[1] The program also identified new risks with the life-support system, aerial refueling, and tire service life, described below. The status of the Department of Defense's (DOD) efforts to address these issues is as follows.

Technical Risks Identified In Our Previous Reports

Ejection seat: In 2015, the program discovered that pilots who weigh less than 136 pounds could possibly suffer neck injuries during ejection. Officials stated that the risk of injury is due to the overrotation of the ejection seat in combination with the thrust from the parachute deployment during ejection. The program has explored a number of solutions to ensure pilot safety including installing a switch for lightweight pilots that would slow the parachute deployment, installing a head support panel that would reduce head movement, and reducing the weight of the helmet. The final design completed qualification testing in 2016 and entered production in June 2017.

Engine seal: Officials have identified a design change to address the technical problem that resulted in engine failure in June 2014. This design change was validated and incorporated into production in 2015. Engine contractor officials identified 194 engines that needed to be retrofitted. The engine contractor, Pratt & Whitney, is paying for these retrofits.

Helmet Mounted Display (HMD): During low-light flights, the HMD projects a composite night vision video feed on the pilot's visor. However, the projection system uses back-lit liquid crystal displays, which creates a green glow on the screen as the light escapes through gaps between each pixel. This green glow makes it difficult to see the full resolution of the night vision video feed. Organic light-emitting diode displays avoid this effect by only illuminating the active pixels. The program expects HMDs with this improvement to enter production in early 2019. Figure 8 is a photograph of the HMD.

[1] GAO, *F-35 Joint Strike Fighter: DOD Needs to Complete Developmental Testing Before Making Significant New Investments*, GAO-17-351 (Washington, D.C.: Apr. 24, 2012).

Figure 8: The F-35 Helmet Mounted Display (HMD)



Source: Lockheed Martin. | GAO-18-321

F-35C catapult launches: In 2016, officials identified issues with violent, uncomfortable, and distracting movement during catapult launches. Specifically, officials stated that the nose gear strut moves up and down as an aircraft accelerates to takeoff, which can cause neck and jaw soreness for the pilot because the helmet and oxygen mask are pushed back on the pilot's face during take-off. This can be a safety risk as the helmet can hit the canopy, possibly resulting in damage, and critical flight data displayed on the helmet can become difficult to read during and immediately after launch due to the rotation of the helmet on the pilot's head. Officials evaluated several options for adjusting the nose gear to alleviate the issue, but determined that none of the options would significantly affect the forces felt by the pilot. Officials subsequently assembled a team to identify a root cause and a redesign. Two changes are being implemented to reduce shaking on carrier launches:

1. The force with which the aircraft is held in place while the engine builds thrust in preparation for takeoff has been reduced by adjusting the hold-back bar, reducing the maximum acceleration the pilot experiences during launch, as shown in figure 9.

Figure 9: An F-35C on USS *George Washington*



Source: Lockheed Martin. | GAO-18-321

2. New procedures for seating and strapping in pilots before launch have been implemented including tightly strapping down the pilots' restraints and ensuring the back of pilots' helmets are off the headrest.

Newly Identified Technical Risks

Aerial refueling probes: The F-35B and F-35C variants use a "hose and drogue" system where an aerial refueling tanker aircraft extends a long, flexible refueling hose and a parachute-like metal basket that provides stability, and the receiving aircraft then connects to the drogue basket with its extendable refueling probe, as shown in figure 10. From April 2014 to August 2017, 21 incidents have occurred where the F-35's aerial refueling probes broke off while conducting aerial refueling, leading to a restriction of aerial refueling operations. The Navy and Air Force are investigating the issue and implementing improvements to reduce these incidents:

1. Pilot training improvements have been completed.
2. Improved inspection of KC-10 aerial refueling equipment has been implemented.
3. Software improvements to reduce the pilot's workload during refueling are planned to enter flight testing in May 2018.
4. A stronger refueling probe is in development.

Figure 10: F-35B Aircraft Refuel from a KC-130 Aerial Refueling Tanker Using Hose and Drogue Refueling Equipment



Source: Lockheed Martin. | GAO-18-321

Tire service life: The average service life of tires on the F-35B is below 10 landings, so Lockheed Martin has been directed to develop a tire that can withstand greater than 25 conventional full-stop landings. The program reports that Lockheed Martin has selected a new tire and expects to test these tires by late 2018. Figure 11 shows an F-35B during a landing.

Figure 11: An F-35B on USS *America*



Source: Lockheed Martin. | GAO-18-321

Life-support system (LSS): From May to August 2017, six events occurred where pilots reported physiological symptoms of oxygen deprivation, though no common cause was identified. However, three issues with components related to the LSS are being examined:

1. A breathing regulator on the pilot's seat is failing at a high rate, contributing to one oxygen deprivation event. Slow progress on a root-cause corrective action has led the program to consider alternative suppliers for this component.
2. An antisuffocation valve that opens when the breathing regulator fails is itself failing to consistently open, creating a risk that unconscious pilots ejecting over water may drown. The valve's manufacturer is investigating potential improvements, and F-35 units are inspecting and cleaning the valves.
3. The rate at which the cockpit's internal pressure changes can potentially cause significant debilitating ear pain or injury to the sinus. In addition to potential pain experienced by the pilot, loss of situational awareness during complex maneuvers could cause the aircraft to crash.

Appendix IV: Comments from the Department of Defense

ASSISTANT SECRETARY OF DEFENSE
3600 DEFENSE PENTAGON
WASHINGTON, DC 20301-3600

ACQUISITION

May 25, 2018

Mr. Michael J. Sullivan
Director, Contracting and National Security Acquisitions
U.S. Government Accountability Office
441 G Street, NW
Washington DC 20548

Dear Mr. Sullivan:

This is the Department of Defense (DoD) response to the Government Accountability Office (GAO) Draft Report, GAO-18-321, "F-35 JOINT STRIKE FIGHTER: Development is Nearly Complete but Deficiencies Found in Testing Need to be Addressed," dated April 2, 2018 (GAO Code 102111).

The Department acknowledges receipt of the draft report. As more fully explained in the enclosure, the Department concurs with both recommendations.

We appreciate the opportunity to comment on the draft report. Should you have any questions, please contact Col David R. Buchanan who can be reached at 703-692-5932 or david.r.buchanan.mil@mail.mil.

Sincerely,

Kevin M. Fahey

Enclosure:
As stated

GAO DRAFT REPORT DATED APRIL 2, 2018
GAO-18-321 (GAO CODE 102111)

"F-35 JOINT STRIKE FIGHTER: Development is Nearly Complete but Deficiencies Found in Testing Need to be Addressed"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommends that the Secretary of Defense direct the F-35 program office to resolve all critical deficiencies before making a full-rate production decision.

DoD RESPONSE: Concur. Resolution of critical deficiencies identified during testing of the F-35 program will be addressed according to established, time-tested processes applicable to all Department of Defense acquisition programs. Milestone Decisions, to include a full-rate production decision, are governed by DoDI 5000.02, "Operation of the Defense Acquisition System." DoDI 5000 .02 states that, "Except as specifically approved by the MDA, critical deficiencies identified in testing will be resolved prior to proceeding beyond LRIP or limited deployment. Remedial action will be verified in follow-on test and evaluation." The F-35 program, U.S Services and international partners track deficiency reports (DRs) and prioritize fixes to those with the greatest impact to operational capability, readiness and affordability. The Department expects the F-35 Program to resolve all critical deficiencies prior to entering Initial Operational Test and Evaluation (IOT&E), with either a fix, through a Service Operational Test Agency approved work around, or through a formal acceptance of the deficiency. Following IOT&E, the Defense Acquisition Executive will review the F-35 program for a full-rate production decision. The full-rate production decision will include an assessment of SDD and IOT&E DRs, as well as follow-on improvement DRs deferred for post-SDD action.

RECOMMENDATION 2: The GAO recommends that the Secretary of Defense direct the F-35 program office to identify what steps are needed to ensure the F-35 meets reliability and maintainability requirements before each variant reaches maturity and update the Reliability and Maintainability Improvement Program with these steps.

DoD RESPONSE: Concur. The Department will work with the F-35 Program to update the Reliability and Maintainability Improvement Program, with the necessary steps to ensure continued progress towards the reliability and maintainability goals for each aircraft variant at maturity.

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Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

Michael J. Sullivan, (202) 512-4841 or sullivanm@gao.gov

Staff Acknowledgments

In addition to the contact named above, the following staff members made key contributions to this report: Justin Jaynes (Assistant Director), Jennifer Baker, Emily Bond, Matthew T. Crosby, Desirée E. Cunningham, Laurier R. Fish, Kristine R. Hassinger, Helena Johnson, Karen Richey, Hai Tran, Nathaniel Vaught, and Robin M. Wilson.

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